

## TRAWLED CATCHES IN NORTHERN MORETON BAY

### II. CHANGES OVER TWO YEARS

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#### ABSTRACT

The trawled biota was sampled at monthly intervals for two years at three selected sites in northern Moreton Bay. This was part of a series of baseline studies of possible effects of enlarging the Brisbane Airport.

Most of the species-in-sites showed significant annual cycles, these being most developed at the site furthest from the mainland; other intersite differences are detailed.

A majority of the species-in-sites showed significant reductions in catches in the second compared with the first year of sampling, and annual cycling was also less developed in the second year. Residuals from annual cyclical regressions were examined by further regressions and in numerous species-in-sites there were significant linear reductions in catches. Ten-year cyclical regressions, which probably mimic long-term logistic declines, gave significant results in a majority of cases.

The major changes in the biota from year 1 to year 2 are probably related to a long period of warm and dry conditions during year 2. A very prolonged study would have been necessary before the effects of weather could have been quantified, and a basis found for assessing potential changes due to man.

Analyses were also conducted on data summed over the three sites. A higher proportion of species now showed significant annual cycling, and of these fewest attained their estimated times of maxima in spring, and most in summer. Comparing with previous results on the macrobenthos (Stephenson 1980c) supports the hypothesis that the benthos is largely controlled by nekto-benthos and nekton.

Comments are given on the total numbers of individuals of species in the combined catches at the three sites in terms of both faunistic recordings and numerical importance from a commercial viewpoint.

#### INTRODUCTION

In an early paper (Stephenson, Chant and Cook 1982) we have given the background to the present work. It is an attempted baseline study whereby the effects of enlargement of the Brisbane Airport upon the trawled biota may be evaluated. The study began in April 1979 and involved sampling at three sites for 26 lunar months (2 years). By this time engineering operations at the airport were about to commence, and results are reviewed primarily to assess the adequacy of a two year baseline study.

Descriptions of the three sites and a map were given previously; site 1 in Bramble Bay is close to the airport itself, site 2 near Redcliffe is in the

nature of a control site, and site 3 near Middle Banks is close to the area of dredging fill for the airport.

At each site in each month, eight catches were made using three sampling alternatives: four catches involved port nets and four starboard, four with the tide and four into it, and four at midday and four at dusk. In the previous paper after an analysis of variance approach it was decided to sum catches of each species over these three alternatives. For present purposes the species considered at a given site were those in which more than 10 individuals were obtained and which occurred in more than two of the 26 times.

The 70 species which are considered are listed in alphabetical order in Appendix 1. Subsequent references are to generic names unless more than one species of a genus is listed in Appendix 1.

### CYCLICAL REGRESSIONS

After attempting a variety of analytical approaches the use of cyclical regressions appeared the most promising. They have produced conceptual sense from benthic data in northern Moreton Bay (Stephenson 1978, 1980a, b, c), but Burgess (1980) using the same techniques obtained significant cycles in only 15/61 trawled fish species over 17 times (over two years).

### DATA TRANSFORMATIONS

Prior to effecting cyclical regressions, the data were transformed so that the distributions approximated to a symmetrical bell-shaped curve. This was obtained by operating on the skewness of the data. A similar approach was used previously by the senior author (Stephenson and Burgess, 1980). Moment coefficients of skewness were obtained from the recordings of each species in the different times with a series of root transformations from 1 to 8 incremented by unity (i.e.  $n^{1/1}$  to  $n^{1/8}$ ). Two options are then available either to select the transformation which approximates most closely to completely removing skewness from the data (moment coefficient of zero) or to retain some of the original skewness (moment of 0.5). A trial of the two alternatives was made using summed data from the three sites and showed that with ca zero moment coefficients the  $R^2$  value for annual cyclical regressions averaged over all species increased by less than 1% over that when using an 0.5 moment. It was decided to use moment coefficients of 0.5; this level was chosen because it may be used as a limit for normality of distribution prior to statistical testing. Thus Pearson and Hartley (1966) quote 5% points for the distribution of moment coefficients of skewness for samples which deviate significantly from a normal distribution. For less than 50 samples, the moments are always greater than 0.53.

In some species 8th root transformations did not reduce the moments to 0.5 and in these cases the 8th root was used.

Annual cyclical regressions (periodicity of 13 time units) were carried out on site 1 data for 49 species, appropriately transformed. The values of  $R^2$  (proportion of explained variation) are readily tested for significance. It should be noted that, because the original data were used to select the

transformations, this reduces by one the degrees of freedom for significance testing. Twenty-seven of the 49 species gave significant cycles.

### RUNNING AVERAGES

Perusal of the original data at all sites showed considerable 'saw tooth' variations between species recordings in consecutive times. To reduce this source of variation, running averages of recordings over two consecutive times were used. These averages were then transformed and annual cyclical regressions were effected.

Results using site 1 data gave 30 of the 49 species with significant cycles. It seems probable that by extending the use of running averages to cover three times, higher average  $R^2$  values could be obtained. This was not effected primarily because of the risk of generating spurious cycles (Cole) 1954. Most future calculations were based on running average data using two consecutive times.

### ANNUAL AND NEAR-ANNUAL CYCLES

Originally an interest was declared in annual cycles but after analyses had been completed it was suspected, as in the case of the macrobenthos (Stephenson 1980c) that the near annual periodicity might not be precisely 1 year ( $T=13$ ). A series of cyclical regressions with periodicities of  $T=11$  to  $T=16$  (with increments of unity) was effected. The numbers of species giving  $R^2$  values which reached levels of significance for each periodicity in each site are given in Table 1.

TABLE 1: NUMBERS OF SPECIES WITH  $R^2$  ABOVE LEVEL FOR SIGNIFICANCE WITH PERIODICITIES OF 11 TO 16 AT EACH OF THE SITES.

Site	Periodicities (13=1yr)						Total no. of spp. in sites
	11	12	13	14	15	16	
1	27	31	30	29	27	24	49
2	27	31	30	30	27	26	48
3	36	38	43	45	45	41	53
Sum	90	100	103	104	99	91	150

At sites 1 and 2 the optimal near annual periodicity is 12/13 of a year (48 weeks) but at site 3 it is ca 14.5/13 of a year (1 year and 6 weeks). It is noteworthy that in the present results, as in the macrobenthos from an earlier period, the inshore populations cycle slightly faster than one per year (Stephenson 1980c). No satisfactory explanation can be offered.

Overall the results confirmed the selection of one year cycles ( $T=13$ ) for further study.

### HALF YEAR CYCLES AND KURTOSIS IN THE DATA

It has been shown earlier (Stephenson 1978) that addition of a half annual cycle to an annual one can mimic a platykurtotic annual cycle and that subtraction can mimic a leptokurtotic cycle.

Cyclical regressions with a half annual cycle ( $T=6.5$ ) were performed on the residuals from annual cycles using site 1 data; these can be assumed to be approximately normally distributed.

The regressions gave an average increment in  $R^2$  values of only 0.197 and overall the effect is negligible. However nine species did give significant increments in  $R^2$ , viz. *Leiognathus*, *Charybdis callianassa*, *Thrissocles*, *Johnius*, *Penaeus esculentus*, *Trachypenaeus*, *Saurida undosquamis*, *Platycephalus* and *Portunus sanguinolentus*.

### ANNUAL CYCLES ON DATA FROM SINGLE SITES

Results are given in Appendix 2A-C and show that 30 (out of 49) species gave significant cycles at site 1 with the average  $R^2$  0.357, at site 2 the numbers were 30 (out of 48) species with average  $R^2$  0.414, and at site 3 forty-three (out of 53) species with average  $R^2$  0.517.

It is concluded that the preponderant overall trend in the data is conformity with annual cycles, and that the trend becomes more noticeable as one moves from sites 1 and 2 to site 3. This may be partially because of differences in the species which were recorded from the three sites. Average  $R^2$  values were then obtained for those species with significant cycles which occurred at all three sites and these were 0.424, 0.487, and 0.571 for sites 1, 2, and 3 respectively. It is clear that at least part of the difference is due to conditions at the different sites.

Values of the times (0 to 12.9) in which species with significant cycles were estimated to attain their annual maxima are also given in Appendix 2A-C. These times were adjusted to 'real' times, bearing in mind that the running average times were 0.5 units advanced. Plotting frequency distribution diagrams of these times at each site separately showed at most indistinct patterns. Kolmogorov-Smirnov two sample tests failed to show either significant differences or significant similarities between any of the pairs of sites in any of the other regression derivatives.

Twenty-seven species have significant annual cycles at more than one site and these can be grouped as follows with respect to synchrony of cycles:

#### I. Species at three sites

(a) Nearly synchronised (estimated times of maxima 1 time unit or less apart):

*Caranx*, *Penaeus esculentus*, *Saurida undosquamis*.

(b) Roughly synchronised (estimated times  $> 1$ ,  $< 2.5$  apart):

*Alpheus stephensoni*, *Gerres*, *Oratosquilla anomala*, *Penaeus plebejus*, *Selaroides*, and *Thrissocles*.

(c) Not synchronised (estimated times  $> 2.5$  apart):

*Charybdis callianassa*, *Leiognathus*, *Loligo*, and *Trachypenaeus*.

#### II. Species at two sites.

(a) Nearly synchronised ( $< 1$ ):

*Apogonichthys*, *Harengula*, *Johnius*, *Metapenaeus bennettiae*, *Oratosquilla woodmasoni*, *Paramonacanthus*, *Priopidichthys*, *Sillago ciliata*.

(b) Roughly synchronised ( $> 1$ ,  $< 2$ ):

*Alima*, *Pomatomus*.

(c) Not synchronised ( $> 2.5$ ):

*Portunus hastatoides*, *Saurida tumbil*, *Scomberomorus*, *Sillago maculata*.

Overall eleven species are nearly synchronised, eight roughly synchronised and eight are not synchronised. No clear patterns emerge within the groups, for example there is no consistent tendency for species which are believed to enter the Bay from the Pacific Ocean to reach their maxima first at site 3 which is in closest contact with the Ocean. There is a hint of a similarity amongst the eight non-synchronised species, five of which are suspected to spend most or all of their life cycles within Moreton Bay, (*Charybdis callianassa*, *Leiognathus*, *Loligo*, *Portunus hastatoides* and *Sillago maculata*). From this it can be argued that in these species within-Bay movements are occurring.

### LONGER TERM TIME CHANGES ON SINGLE SITES

The data set showed that a majority of species had lower recordings in the second year of sampling. Paired  $t$  tests were carried out using transformed data, with pairing of respective times of the two years. Nineteen species had significantly lower catches in the second year at site 1 (site 1 spp. 5, 8, 10, 11, 15, 18, 20, 26, 27, 29, 33, 35, 38, 40, 41, 42, 43, 45, 46). There were 12 equivalent species at site 2 (site 2 spp. 1, 7, 8, 10, 13, 17, 20, 29, 32, 35, 38, 39), and 19 at site 3 (site 3 spp. 4, 6, 7, 10, 11, 15, 20, 23, 25, 27, 30, 33, 34, 36, 38, 39, 43, 49, 50). There was only one example of a significantly increased population in the second year: site 3 sp. 41. It is evident that

there were widespread reductions in populations in the second year of sampling.

It was suspected that cycles were more weakly developed in the data from the second year. At each site annual cyclical regressions were performed separately on each year of data. In these running averages were not used because of the relatively short time periods. The transformations applied to each species were those required to reduce skewness in the two years of data, and not each year separately — this facilitates inter-year comparisons. Results on each of the sites are given in Table 2 and show that fewer species followed cycles in the second year, especially at site 1.

TABLE 2: NUMBER OF SPECIES WITH SIGNIFICANT ANNUAL CYCLES.

Site	Yr. 1	Yr. 2
1	20	6
2	27	13
3	35	19

To evaluate the importance of times changes other than annual cycles in terms of proportions of variance, regressions were performed on the residuals from the cyclical regressions with period 1 year.

Linear regressions of residuals against times showed for site 1, 20 species with significant effects, for site 2 there were 17 and for site 3, 19 species. In each significant case the regression line had a negative slope.

It seems likely that the declines shown in the residuals follow curvilinear rather than linear trends, and while these are likely to follow logistic rather than sinusoidal curves, the latter can be regarded as acceptable mimics of the logistic. Preliminary computations suggested that a cycle of longer than seven years was required and 10 years cycling was arbitrarily chosen. At each of the sites more species showed significant 10 year regressions than linear regressions on the residuals, with numbers at sites 1, 2 and 3 as 29, 24 and 32 respectively (see Appendices 2A–C).

#### ANALYSES ON DATA SUMMED OVER SITES

Some of the lack of consistency between sites may have been due to random between-site variations. To obtain an overall view, species recordings were summed over sites, and the analyses repeated. Results are given in Appendix 2D.

Of the 70 species all but 18 gave significant annual cycles, and these 18 were concentrated in the lower end of the abundance hierarchy.

Estimated times of attainment of annual maxima in the 52 conforming species are given as a frequency distribution diagram in Fig. 1. This shows that 26 of the maxima occur in the 5/13ths of the year between mid October and late February, and that the fewest maxima (1 per four weeks) occur from mid June to mid September. The species with warm weather maxima are: *Charybdis callianassa*, *Apogon*, *Loligo*, *Metapenaeus bennettiae*, *Pomatomus*, *Caranx*, *Penaeus*

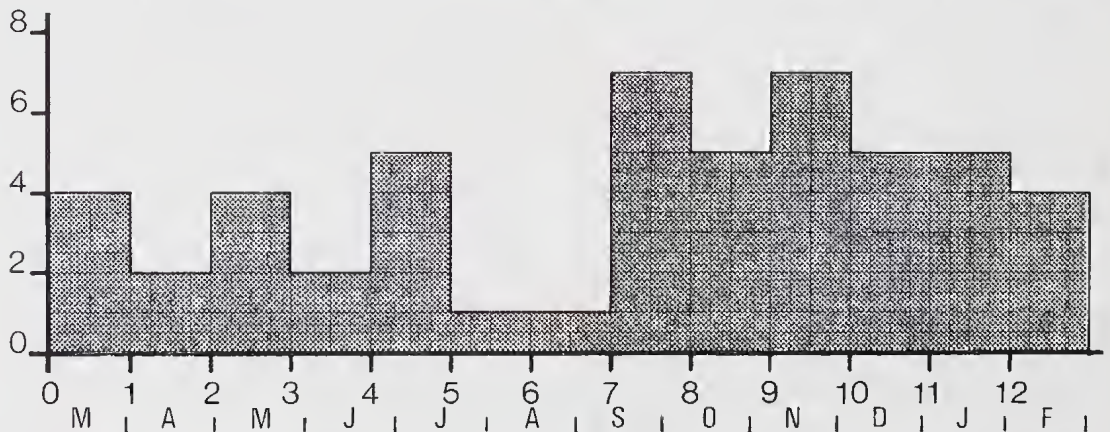


FIG 1: Histogram showing numbers of species (vertically) in pooled catches from sites 1 + 2 + 3 which attained their estimated times of maxima in each 1/13th of the year starting April 1st (horizontally). Times between 0 and 0.99 are given in the interval after zero, and so on until times from 12.0 to 12.99 in the interval after 12. Calendar months also given.

*esculentus*, *Pelates*, *Gerres*, *Trachurus*, *Harengula*, *Oratosquilla anomala*, *Saurida tumbil*, *Selaroides*, *M. endeavouri*, *Alpheus stephensoni*, *Charybdis truncata*, *Pseudorhombus* spp. juv., *Scomberomorus*, *O. woodmasoni*, *O. interrupta*, *Alima*, *Suggrundus*, *Odontodactylus*, *Cepola*, and *Portunus rubromarginatus*.

Ten-year cyclical regressions were carried out on the residuals from annual cycles: 44 species showed significant effects.

#### CLIMATIC DATA

It seemed possible that the weak annual cycling in the second year was due to climatic irregularities. Climatic data (from Brisbane weather station) for 20 years including the years of sampling, were recompiled so that each year began in March, i.e. the beginning of the month before the first sampling.

Annual rainfall and average temperatures are given in Table 3 together with their conversions to units of standard deviation +/— from the means. In the rainfall data six years gave (absolute) standard deviations of greater than unity (1967, 1968, 1970, 1972, 1977 and 1979); on this basis 1979 (the first year of sampling) had unusually

TABLE 3: ANNUAL RAINFALLS (IN MM) AND ANNUAL AVERAGES OF TEMPERATURES (IN °C) FOR 20 YEARS, EACH BEGINNING MARCH 1ST.

Year	Rainfall		Temperature	
	Yearly total	Units std dev. +/- mean	Average	Units std dev. +/- mean
1961	996	-0.5	20.48	-1.0
62	976	-0.6	20.46	-1.0
63	1338	0.4	20.43	-1.1
64	1115	-0.2	20.65	-0.6
65	1031	-0.4	20.77	-0.4
66	1375	0.5	20.44	-1.1
67	1822	1.8	20.58	-0.8
68	522	-1.8	20.94	0
69	1178	0	21.08	0.3
1970	1970	2.2	20.69	-0.5
71	1144	-0.1	20.61	-0.7
72	1632	1.2	21.01	0.1
73	1056	-0.3	21.77	1.7
74	1492	0.9	20.61	-0.7
75	1148	-0.1	21.02	0.2
76	1076	-0.3	21.28	0.7
77	659	1.4	21.61	1.4
78	985	-0.5	20.90	-0.1
79	748	-1.2	21.76	1.7
1980	1374	0.5	21.85	1.9
Mean	1181.9		20.95	

low rainfall. In the temperature data 1980 was the warmest year of all, and 1979 was, approximately coequally with 1973, the second warmest year of all. In two years there were both unusual annual rainfalls and unusual temperatures; these were 1977 and 1979.

Data were then considered on a monthly basis and the numbers of months which had weather continuously greater than or less than the monthly averages over the 20 years were noted. The outstanding periods are: for rainfall May 1979 to April 1980, 12 months of low rainfall; and for temperature June 1979 to Nov. 1980, 18 months of high temperatures. In combination there was a continuous period of June 1979 to April 1980 (10 months) in which there were below average rainfalls and above average temperatures. A shorter period of continuously unusual weather with low rainfalls and high temperatures occurred from July to Nov. 1977.

#### DISCUSSION

The data consisted of recordings of species in three selected sites in Moreton Bay at intervals of four weeks for a two year period. These data were separately analysed on a site by site basis and also using the summed recordings of species in the three sites. Analyses involved determination of running averages of species recordings, transformations to reduce moment coefficients of skewness to as close as possible to 0.5, and annual cyclical regressions.

The main trend in the data was of annual cycling, with this slightly more developed at site 3 than at the other two sites. These differences seem related to abiotic perturbations: deviations from regular seasonal changes in abiotics will almost certainly be greatest at Bramble Bay which is close to the Brisbane River, and least at Middle Banks which is in closest contact with the Pacific Ocean.

Catches of many species were significantly lower and annual cycles were less developed during the second year of sampling. The residuals from annual cycles in many cases showed significant linear declines over time, but a more effective model of the declines was obtained using 10 year cyclical regressions. The declines in population are probably caused by abnormal abiotic conditions. Either the abnormal weather of 1977 is operating after about a 1½ year delay or the abnormal weather of 1979 and 1980 operates with virtually no delay, or there is a combined effect. The present data do not permit choice between these alternatives.

We now view the results from the aspect of assessing changes due to airport construction. It is evident that the present results do not provide an effective baseline. Massive changes have occurred from one year to another without any known or suspected human cause, and comparable if less extreme changes can be expected in the future. One suspects that for an effective baseline study something in excess of 10 years of data would be required. It is unreasonable to expect a lead time of a decade before man-made changes will impinge upon a marine environment.

From the aspect of airport construction it is clearly necessary to consider each site separately. Using data summed over sites led to some clarification, and it was possible to divide the species into two broad groups, those with maximum catches in colder months (18 spp.) and in warmer months (32 spp.) respectively.

In a previous paper (Stephenson, Cook and Newlands, 1978) it was postulated that fish predation had important effects on the macrobenthos. Later work (Stephenson 1980a) showed that the maximum rate of recruitment of the benthos was in August/September and of depletion approximately in December. The latter was attributed to mobile predators or 'disturbers' (fish and prawns), but because only catch data on prawns were available, only relationships between the macrobenthos and prawns could be investigated (Stephenson 1980b). No relevant information on seasonality of fish catches were then available. Seasonal data on the total catches of trawled organisms are now provided, and have been given in Fig. 1 which shows fewest trawled species with a maximum in Aug./Sept. This is the time of maximum benthic recruitment. The present results support the previous work which suggested that benthos is controlled by nekton and nekto-benthic organisms.

Species groupings, based on life styles and/or taxonomic affinities are given in Table 4, and information upon abundances and annual cycles within groups are now considered. (It should be noted that this grouping excludes miscellaneous fish and miscellaneous crustaceans). Significance of annual cycles show some relationships to the taxonomic groups within the catches. Thus all seven stomatopods except the uncommon *Anchisquilla* show highly significant cycles, while three of the six commoner portunids fail to show them. Results on annual cycling of the prawn species can be compared with those obtained by Stephenson and Williams (1981), in analyses of eight years of (weight) catches from Moreton Bay.

There is agreement in the occurrence of significant cycles in the species common to the two lists except for *P. merguensis* which was sparsely represented in the present catches. However there are noticeable differences between the estimated times of maximum catches by Stephenson and Williams (1981, Table 12) and those obtained in the present work. The latter agree reasonably well with the respective commercial fishing seasons, (see Stephenson and Williams Table 13).

TABLE 4: CONSOLIDATED RESULTS, SPECIES IN ECOLOGICAL OR TAXONOMIC GROUPS. SIGNIFICANCE AT 0.01 LEVEL\*\*, AT 0.05 LEVEL\*.

Group	Species	Annual cycles Abundance (2 yr catches)	Signif.	Est. time
				max.
Abundant trash fish	<i>Leiognathus</i>	31777	*	early Sept.
	<i>Paramonacanthus</i>	20854	**	late May
	<i>Apogon</i>	14978	**	mid Feb.
	<i>Polynemus</i>	6370		N
Pilchards etc.	<i>Thrissocles</i>	1870	**	late Oct.
	<i>Hyperlophus</i>	978		N
	<i>Harengula</i>	696	**	mid Jan.
Pelagic fish	<i>Pomatomus</i>	1381	*	mid Feb.
	<i>Caranx</i>	1055	**	late Jan.
	<i>Trachurus</i>	720	**	mid Nov.
	<i>Selaroides</i>	362	**	early Feb.
	<i>Scomberomorus</i>	154	**	early March
Bottom dwelling fish	<i>Callionymus limiceps</i>	1040	**	mid July
	<i>C. belcheri</i>	754	**	mid June
	<i>Pseudorhombus</i> sp. juv.	189	**	late March
	<i>Platycephalus</i>	114	*	early Aug.
	<i>Pseudorhombus arasius</i>	109	*	late July
	<i>Suggrundus</i>	98	**	late Nov.
	<i>Cynoglossus</i>	25		N
Whiting	<i>Sillago maculata</i>	2547	**	early Aug.
	<i>S. ciliata</i>	50	**	early Nov.
Grinner	<i>Saurida undosquamis</i>	2757	**	early May
	<i>S. tumbil</i>	471	**	mid Jan.
Toad fish	<i>Spheroides pleurostictus</i>	252		N
	<i>S. hamiltoni</i>	123	*	early June

TABLE 4: (Continued)

Group	Species	Abundance (2 yr catches)	Annual cycles Signif. Est. time max.
Penaeid prawns	<i>Metapenaeus bennettiae</i>	9449	** early Dec.
	<i>Penaeus plebejus</i>	4415	** mid Oct.
	<i>Trachypenaeus</i>	1074	** mid Feb.
	<i>Metapenaeopsis</i>	1037	** mid Oct.
	<i>P. esculentus</i>	986	** mid Feb.
	<i>Metapenaeus endeavouri</i>	328	** late Dec.
	<i>P. merguensis</i>	26	N
Portunids	<i>Charybdis callianassa</i>	15469	** late Dec.
	<i>Portunus pelagicus</i>	4111	N
	<i>P. hastatoides</i>	1531	N
	<i>P. sanguinolentus</i>	280	N
	<i>C. truncata</i>	222	** mid Dec.
	<i>Thalamita</i>	175	** early Oct.
	<i>P. rubromarginatus</i>	29	** early Dec.
Stomatopods	<i>Oratosquilla anomala</i>	588	** mid Dec.
	<i>O. woodmasoni</i>	110	** late Dec.
	<i>O. interrupta</i>	106	** early Jan.
	<i>Alima</i>	104	** late Dec.
	<i>Odontodactylus</i>	69	** mid Jan.
	<i>Anchisquilla</i>	11	N
Alpheids	<i>Alpheus stephensoni</i>	296	** mid Nov.
	<i>A. distinguendus</i>	51	N
Scyllarids	<i>Thenus</i>	45	N
	<i>Scyllarus</i>	44	N
Cephalopods	<i>Loligo</i>	13825	** mid March
	<i>Sepia</i>	135	N
	<i>Octopus</i>	97	* mid July

Within several of the groups in Table 4 there is reasonable consistency in the estimated times within the year of attaining maximum catches. For the pelagic fish with the exception of *Scomberomorus* all maxima occur in summer (mid-November to mid-February), for the bottom fish excepting *Suggrundus* all are in cooler weather (late March to early August), the five penaeids which showed significant cycles gave maxima in late spring to summer (mid-October to mid-February), the four portunids from early October to late December, and the five stomatopods from mid December to mid January.

Finally comments are offered on the relative abundance of the different groups in Table 4 and of the species within them. It is usual in faunistic work for abundances to be given in graded terms

such as 'abundant' and 'very common', but it is unusual for such terms to be derived from data as voluminous as those of the present study. It is easy to arrange all the species in an hierarchical order of abundance and when this has been done (Appendix 2D) the difficulties of separating grades of abundance become evident. Other than dissecting off the first species (*Leiognathus*) and the last (*Anchisquilla*), there are few obvious break points. Within the groups (see Table 4) discontinuities are more evident, for example *Polynemus* is the lowest numerically abundant trash fish, *Thrissocles* the most abundant pilchard etc., and *Sillago maculata* is the more abundant whiting.

There are constraints on the interpretation of the abundance data in Table 4 for two reasons. The first is that they are likely to be biased by unusually high recordings during one or another sampling period. This is emphasised by (a) the stringency of transformations required to decrease the skewness of the data, and (b) the knowledge that both absolute and relative abundances change from year to year. This is apparent by comparing Appendix 1 in Stephenson, Chant and Cook (1982) giving first year abundances in hierarchical order with Appendix 2D of the present paper, which gives the abundance hierarchy using two years of data. Any conclusions from the present work need the overall qualification that they apply only to the summated data from the present two years sampling.

Accepting these qualifications and equating values which by subjective judgement appear approximately coequal, abundance hierarchies can be given. Between the thirteen groups of Table 4 the hierarchy with abundances in parenthesis is: abundant trash fish (73979) > portunids (21817) > penaeids (17315) > cephalopods (14057) > pelagic fish (3672) = pilchards (3544) = grinnings (3228) > whiting (2597) = bottom fish (2329) > stomatopods (988) > toad fish (375) = alpheids (347) > scyllarids (89). Abundances within the groups of Table 4, provide more precise information than has hitherto been available on a number of taxa. For example the numbers of stomatopods recorded from northern Moreton Bay are greatly in excess of the total numbers of all species recorded from Australian waters by Stephenson and McNeill (1955). We can now arrange species in the following hierarchy: *Oratosquilla anomala* (588) > *O. woodmasoni* (110) = *O. interrupta* (106) = *Alima* (104) > *Odontodactylus* (69) > *Anchisquilla* (11). A similar lack of precision applied to data on

portunids (see Stephenson 1972 for literature). The species in the present collection can be arranged as follows: *Charybdis callianassa* (15469) > *Portunus pelagicus* (4111) > *P. hastatoides* (1531) > *P. sanguinolentus* (280) > *C. truncata* (222) > *Thalamita* (175) > *P. rubromarginatus* (29).

A grouping alternative to that of Table 4 would be into species caught for the market (prawns, *Portunus pelagicus*, alpheids, *Thenus*, *Loligo* and say half of *Sillago* spp.), those of no commercial value (e.g. trash fish), and those of 'negative value' in the sense of removal and non-sale of fish caught by other techniques (e.g. angling). The approximate respective numbers in these groups taken from Table 4 (i.e. excluding miscellaneous fish and crustaceans) are: 36923, 102313, 5085. The direct damage to angling fish comprises only 3.5% of the total catch, and a relatively large proportion of trawled individuals is wasted from an economic viewpoint (74%).

#### ACKNOWLEDGEMENTS

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#### APPENDIX 1

##### SPECIES LIST

The 70 species considered, in alphabetical order. Authors and systematic positions given only for species not listed in Stephenson, Chant & Cook (1982).

*Adenopogon rosiegaster* (Ramsay & Ogilby), Apogonidae, Pisces; *Alima laevis*; *Alpheus distinguendus*; *A. stephensoni*; *Anchisquilla fasciata* (de Haan), Stomatopoda, Crustacea; *Apogon quadrifasciatus*; *Apogonichthys ellioti*;

*Callionymus belcheri*; *C. limiceps*; *Caranx malam*; *Centropogon marmoratus*; *Cepola australis* Ogilby, Cepolidae, Pisces; *Charybdis callianassa*; *C. truncata*; *Cynoglossus bilineatus* (Lacépède), Cynoglossidae, Pisces; *Dorippe australiensis*; *Euristhmus lepturus*; *Gerres ovatus*; *Harengula castelnaui*; *Hyperlophus translucidus*; *Johnius australis*; *Leiognathus moretonensis*; *Loligo formosana*; *Metapenaeopsis novae-guinae*; *Metapenaeus bennettiae*; *M. endeavouri*; *Minous versicolor*; *Neoarius australis* (Günther), Trachysuridae, Pisces; *Octopus membranaceus*; *Odontodactylus cultrifer*; *Oratosquilla anomala*; *O. interrupta*; *O. woodmansoni*; *Paramonacanthus oblongus*; *Parapercis nebulosus* (Quoy & Gaimard), Parapercidae, Pisces; *Pelates quadrilineatus*; *Penaeus esculentus*; *P. merguensis* de Man, Penaeidea, Crustacea; *P. plebejus*; *Phalangipus australiensis*; *Platycephalus indicus*; *Polynemus multiradiatus*; *Pomatomus saltatrix*; *Portunus hastatoides*; *P. pelagicus*; *P. rubromarginatus* (Lanchester), Portunidae, Crustacea; *P. sanguinolentus*; *Priacanthus macracanthus*; *Priopidichthys marianus*; *Pseudorhombus arsius*; *Pseudorhombus* spp. (juvs); *Saurida tumbil*; *S. undosquamis*; *Scomberomorus queenslandicus*; *Scyllarus tuberculatus* (Bate), Scyllaridae, Crustacea; *Selaroides leptolepis*; *Sepia aculeata*; *Siganus spinus*; *Sillago ciliata* Cuvier, Sillaginidae, Pisces; *S. maculata*; *Spheroides hamiltoni*; *S. pleurostictus*; *Sphyraena obtusata*; *Suggrundus harrisii*; *Thalamita sima*; *Thenus orientalis*; *Thrissocles hamiltoni*; *Trachurus mccullochi*; *Trachypenaeus fulvus*; *Upeneus tragula*.

#### APPENDIX 2

Results of regressions: A site 1, B site 2, C site 3, and D sites 1+2+3. Significance at 0.05 level \*, at 0.01 level \*\*.

Code No.	Species	Abundance (sum over 26 times)	APPENDIX 2A: SITE 1		10 yr Cyc. regr. on resids from 1 yr R <sup>2</sup>
			1 yr Cyclical regressions Root transf	Adjusted R <sup>2</sup> est time max	
1	<i>Leiognathus</i>	4593	8	0.450**	12.7
2	<i>Metapenaeus bennettiae</i>	3844	2	0.181	0.364*
3	<i>Charybdis callianassa</i>	3786	1	0.467**	10.0
4	<i>Penaeus plebejus</i>	3404	2	0.775**	6.9
5	<i>Apogon</i>	3071	1	0.002	0.531**
6	<i>Polynemus</i>	2463	1	0.178	0.257
7	<i>Loligo</i>	2311	1	0.653**	11.9
8	<i>Portunus pelagicus</i>	1512	3	0.378**	8.4



9	<i>Thrissocles</i>	1051	3	0.345*	7.2	0.134
10	<i>Pelates</i>	921	2	0.289*	11.0	0.530**
11	<i>Sillago maculata</i>	691	1	0.312*	2.8	0.435**
12	<i>Johnius</i>	633	2	0.424**	7.4	0.136
13	<i>Harengula</i>	550	1	0.377**	10.2	0.570**
14	<i>Gerres</i>	525	3	0.709**	10.6	0.321*
15	<i>Hyperlophus</i>	486	2	0.104		0.514**
16	<i>Sphyraena</i>	462	1	0.377**	1.7	0.158
17	<i>Penaeus esculentus</i>	299	1	0.526**	12.2	0.075
18	<i>Pomatomus</i>	296	1	0.756**	10.5	0.537**
19	<i>Trachypenaeus</i>	279	3	0.334*	6.5	0.030
20	<i>Paramonacanthus</i>	211	3	0.237		0.271
21	<i>Spheroides pleurostictus</i>	179	3	0.052		0.354*
22	<i>Adenopogon</i>	166	4	0.332*	2.8	0.434**
23	<i>Caranx</i>	158	3	0.825**	11.3	0.323*
24	<i>Oratosquilla anomala</i>	133	1	0.465**	7.4	0.033
25	<i>Centropogon</i>	131	1	0.254		0.172
26	<i>Thalamita</i>	98	2	0.405**	5.8	0.675**
27	<i>Euristhmus</i>	84	2	0.130		0.418**
28	<i>Priopidichthys</i>	83	3	0.735**	7.7	0.097
29	<i>Selaroides</i>	73	8	0.359*	12.5	0.345*
30	<i>Alima</i>	64	2	0.368*	9.2	0.292*
31	<i>Alpheus stephensoni</i>	61	3	0.749**	7.2	0.027
32	<i>Apogonichthys</i>	53	2	0.032		0.424**
33	<i>Dorippe</i>	52	3	0.177		0.639**
34	<i>Spheroides hamiltoni</i>	50	1	0.435**	1.9	0.631**
35	<i>Scyllarus</i>	44	3	0.003		0.298*
36	<i>Scomberomous</i>	43	3	0.130		0.608**
37	<i>Saurida undosquamis</i>	41	8	0.717**	2.0	0.278
38	<i>Phalangipus</i>	38	1	0.064		0.571**
39	<i>Sillago ciliata</i>	38	2	0.356*	7.7	0.483**
40	<i>Siganus</i>	37	4	0.429**	0.7	0.514**
41	<i>Sepia</i>	34	2	0.073		0.661**
42	<i>Upeneus</i>	32	2	0.511**	1.5	0.433**
43	<i>Thenus</i>	27	4	0.215		0.607**
44	<i>Penaeus merguensis</i>	26	2	0.186		0.049
45	<i>Platycephalus</i>	24	2	0.589**	4.9	0.245
46	<i>Pseudorhombus arsius</i>	23	8	0.204		0.801**
47	<i>Portunus sanguinolentus</i>	14	8	0.597**	0.6	0.162
48	<i>Neoarius</i>	12	1	0.083		0.017
49	<i>P. hastatoides</i>	12	2	0.162		0.216

## APPENDIX 2B: SITE 2

1	<i>Paramonacanthus</i>	14793	8	0.370**	1.8	0.569**
2	<i>Leiognathus</i>	14515	2	0.540**	3.4	0.411**
3	<i>Charybdis callianassa</i>	10566	3	0.741**	8.9	0.618**
4	<i>Metapenaeus bennettiae</i>	5283	6	0.669**	9.4	0.017
5	<i>Loligo</i>	4508	3	0.791**	0.9	0.166
6	<i>Apogon</i>	3711	5	0.290*	10.7	0.301*
7	<i>Polynemus</i>	3216	3	0.281*	11.4	0.296*
8	<i>Portunus pelagicus</i>	1458	8	0.030		0.806**
9	<i>Pomatomus</i>	859	2	0.145		0.356*
10	<i>Portunus hastatoides</i>	609	5	0.327*	2.7	0.753**
11	<i>Penaeus plebejus</i>	588	2	0.837**	8.6	0.191

12	<i>Thrissocles</i>	511	1	0.613**	9.5	0.034
13	<i>Hyperlophus</i>	492	4	0.103		0.350*
14	<i>Trachurus</i>	425	5	0.643**	8.6	0.156
15	<i>Trachypenaeus</i>	406	2	0.391**	10.3	0.519**
16	<i>P. esculentus</i>	324	2	0.886**	11.3	0.236
17	<i>Saurida undosquamis</i>	291	2	0.707**	1.2	0.484**
18	<i>Portunus sanguinolentus</i>	266	5	0.203		0.758**
19	<i>Johnius</i>	246	1	0.189		0.055
20	<i>Sillago maculata</i>	206	2	0.105		0.426**
21	<i>Caranx</i>	204	4	0.752**	10.5	0.236
22	<i>Alpheus stephensoni</i>	201	7	0.792**	9.4	0.165
23	<i>Harengula</i>	146	8	0.476**	10.0	0.181
24	<i>Apogonichthys</i>	139	5	0.386**	0.9	0.282
25	<i>Oratosquilla anomala</i>	106	2	0.732**	9.3	0.433**
26	<i>Spheroides pleurostictus</i>	72	4	0.346*	7.5	0.057
27	<i>Gerres</i>	71	2	0.611**	9.2	0.165
28	<i>Scomberomorus</i>	59	1	0.617**	12.1	0.680**
29	<i>Sepia</i>	50	3	0.093		0.714**
30	<i>Callionymus limiceps</i>	48	2	0.218		0.121
31	<i>Selaroides</i>	46	5	0.464**	11.7	0.190
32	<i>Saurida tumbil</i>	42	4	0.428**	3.8	0.707**
33	<i>Spheroides hamiltoni</i>	41	1	0.047		0.307*
34	<i>Alima</i>	40	2	0.668**	10.4	0.268
35	<i>Priacanthus</i>	37	3	0.013		0.522**
36	<i>Sphyræna</i>	37	4	0.061		0.571**
37	<i>Thalamita</i>	34	2	0.792**	8.9	0.169
38	<i>Alpheus distinguendus</i>	31	4	0.078		0.727**
39	<i>Euristhmus</i>	26	8	0.225		0.494**
40	<i>Neoarius</i>	26	8	0.697**	1.1	0.234
41	<i>Priopidichthys</i>	23	5	0.708**	8.4	0.199
42	<i>Oratosquilla woodmasoni</i>	20	4	0.529**	9.1	0.169
43	<i>C. belcheri</i>	19	2	0.027		0.129
44	<i>Siganus</i>	18	8	0.241		0.580**
45	<i>Pseudorhombus</i> spp. juvs	15	8	0.122		0.090
46	<i>O. interrupta</i>	14	5	0.210		0.275
47	<i>Pelates</i>	12	1	0.204		0.324*
48	<i>Sillago ciliata</i>	12	2	0.451**	8.4	0.263

## APPENDIX 2C: SITE 3

1	<i>Leiognathus</i>	12589	1	0.748**	7.1	0.145
2	<i>Apogon</i>	8196	1	0.322*	11.6	0.239
3	<i>Loligo</i>	7481	8	0.590**	11.8	0.825**
4	<i>Paramonacanthus</i>	5850	2	0.706**	1.9	0.571**
5	<i>Saurida undosquamis</i>	2460	2	0.760**	1.0	0.077
6	<i>Sillago maculata</i>	1650	6	0.590**	5.2	0.532**
7	<i>Portunus pelagicus</i>	1124	8	0.037		0.714**
8	<i>Charybdis callianassa</i>	1071	3	0.499**	11.7	0.549**
9	<i>Metapenaeopsis</i>	1035	3	0.830**	7.0	0.258
10	<i>Callionymus limiceps</i>	992	1	0.444**	3.5	0.534**
11	<i>P. hastatoides</i>	910	7	0.447**	7.3	0.511**
12	<i>C. belcheri</i>	735	2	0.634**	2.6	0.410**
13	<i>Caranx</i>	694	1	0.832**	10.8	0.187
14	<i>Polynemus</i>	629	2	0.510**	8.2	0.575**
15	<i>Apogonichthys</i>	601	2	0.467**	0.8	0.393**

16	<i>Saurida tumbil</i>	429	3	0.642**	10.5	0.345*
17	<i>Penaeus plebejus</i>	423	1	0.816**	7.4	0.268
18	<i>Trachypenaeus</i>	389	2	0.694**	7.2	0.265
19	<i>P. esculentis</i>	363	2	0.771**	11.4	0.532**
20	<i>Oratosquilla anomala</i>	350	2	0.917**	9.6	0.212
21	<i>Priacanthus</i>	339	3	0.606**	1.0	0.579**
22	<i>Metapenaeus endeavouri</i>	328	2	0.714**	9.8	0.226
23	<i>M. bennettiae</i>	322	4	0.786**	8.6	0.499**
24	<i>Thrissocles</i>	308	4	0.769**	7.5	0.107
25	<i>Trachurus</i>	295	2	0.174		0.353*
26	<i>Gerres</i>	265	2	0.909**	8.5	0.255
27	<i>Centropogon</i>	247	2	0.558**	3.9	0.396**
28	<i>Selaroides</i>	243	2	0.694**	10.8	0.642**
29	<i>Charybdis truncata</i>	222	3	0.518**	9.3	0.521**
30	<i>Pomatomus</i>	212	3	0.620**	9.1	0.645**
31	<i>Pseudorhombus</i> spp. juvs	175	2	0.625**	0.2	0.016
32	<i>Suggrundu</i>	98	1	0.538**	8.7	0.048
33	<i>Octopus</i>	97	2	0.285*	3.5	0.455**
34	<i>Oratosquilla interrupta</i>	92	2	0.643**	10.1	0.547**
35	<i>O. woodmasoni</i>	90	1	0.584**	9.1	0.053
36	<i>P. arsius</i>	86	2	0.317*	4.5	0.634**
37	<i>Platycephalus</i>	80	1	0.060		0.304*
38	<i>Minous</i>	74	1	0.061		0.235
39	<i>Upeneus</i>	73	2	0.047		0.652**
40	<i>Odontodactylus</i>	69	1	0.740**	10.4	0.002
41	<i>Johnius</i>	53	2	0.647**	8.1	0.111
42	<i>Scomberomorus</i>	52	8	0.325*	10.6	0.593**
43	<i>Sepia</i>	51	3	0.323*	0.9	0.657**
44	<i>Thalamita</i>	43	2	0.085		0.025
45	<i>Alpheus stephensoni</i>	34	8	0.571**	7.9	0.331*
46	<i>Cepola</i>	33	3	0.754**	12.2	0.314*
47	<i>Spheroides hamiltoni</i>	32	1	0.173		0.141
48	<i>Portunus rubromarginatus</i>	29	2	0.839**	8.9	0.332*
49	<i>Paraperis</i>	27	1	0.337*	4.0	0.363*
50	<i>Cynoglossus</i>	25	2	0.213		0.617**
51	<i>A. distinguendus</i>	20	5	0.213		0.546**
52	<i>Thenus</i>	18	5	0.312*	3.4	0.226
53	<i>Anchisquilla</i>	11	1	0.088		0.170

## APPENDIX 2D: ALL SITES

All sites code no.	Species	No.	Sites of occurrence	Annual cycles		
				Root transf	R <sup>2</sup>	T max (adjusted)
1	<i>Leiognathus</i>	31777	1,2,3	1	0.292*	5.5
2	<i>Paramonacanthus</i>	20854	1,2,3	8	0.591**	2.1
3	<i>Charybdis callianassa</i>	15469	1,2,3	2	0.828**	9.8
4	<i>Apogon</i>	14978	1,2,3	8	0.341*	11.3
5	<i>Loligo</i>	13825	1,2,3	8	0.717**	12.5
6	<i>Metapenaeus bennettiae</i>	9449	1,2,3	1	0.512**	8.8
7	<i>Polynemus</i>	6370	1,2,3	2	0.154	
8	<i>Penaeus plebejus</i>	4415	1,2,3	1	0.746**	7.0
9	<i>Portunus pelagicus</i>	4111	1,2,3	3	0.029	
10	<i>Saurida undosquamis</i>	2757	1,2,3	2	0.789**	1.1
11	<i>Sillago maculata</i>	2547	1,2,3	4	0.412**	4.4

12	<i>Thrissocles</i>	1870	1,2,3	2	0.503**	7.6
13	<i>Portunus hastatoides</i>	1531	1,2,3	8	0.103	
14	<i>Pomatomus</i>	1381	1,2,3	1	0.281*	11.5
15	<i>Trachypenaeus</i>	1074	1,2,3	2	0.461**	7.9
16	<i>Caranx</i>	1055	1,2,3	2	0.878**	10.8
17	<i>Callionymus limiceps</i>	1040	2,3	1	0.439**	3.6
18	<i>Metapenaeopsis</i>	1037	3	3	0.831**	7.0
19	<i>Penaeus esculentus</i>	986	1,2,3	1	0.837**	11.5
20	<i>Hyperlophus</i>	978	1,2	3	0.116	
21	<i>Pelates</i>	933	1,2	2	0.289*	11.1
22	<i>Johnius</i>	932	1,2,3	2	0.349*	7.8
23	<i>Gerres</i>	861	1,2,3	2	0.790**	9.8
24	<i>Apogonichthys</i>	793	1,2,3	3	0.433**	0.8
25	<i>Callionymus belcheri</i>	754	2,3	3	0.665**	2.7
26	<i>Trachurus</i>	720	2,3	2	0.580**	8.2
27	<i>Harengula</i>	696	1,2	2	0.548**	10.2
28	<i>Oratosquilla anomala</i>	588	1,2,3	1	0.844**	9.3
29	<i>Sphyraena</i>	499	1,2	1	0.265*	1.9
30	<i>Saurida tumbil</i>	471	2,3	3	0.432**	10.4
31	<i>Centropogon</i>	378	1, 3	1	0.432**	4.2
32	<i>Priacanthus</i>	376	2,3	3	0.502**	0.8
33	<i>Selaroides</i>	362	1,2,3	3	0.719**	11.1
34	<i>Metapenaeus endeavouri</i>	328	3	2	0.714**	9.8
35	<i>Alpheus stephensoni</i>	296	1,2,3	3	0.728**	8.4
36	<i>Portunus sanguinolentus</i>	280	1,2	5	0.217	
37	<i>Spheroides pleurostictus</i>	252	1,2,	1	0.018	
38	<i>Charybdis truncata</i>	222	3	3	0.518**	9.3
39	<i>Neoarius</i>	198	1,2	5	0.411**	0.2
40	<i>Pseudorhombus</i> spp. juvs	189	2,3	1	0.613**	12.9
41	<i>Thalamita</i>	175	1,2,3	1	0.347*	6.8
42	<i>Adenopogon</i>	166	1	4	0.341*	2.8
43	<i>Scomberomorus</i>	154	1,2,3	3	0.484**	12.0
44	<i>Sepia</i>	135	1,2,3	2	0.085	
45	<i>Spheroides hamiltoni</i>	123	1,2,3	1	0.267*	2.4
46	<i>Euristhmus</i>	120	1,2,3	2	0.054	
47	<i>Platycephalus</i>	114	1, 3	1	0.313*	4.6
48	<i>O. woodmasoni</i>	110	2,3	1	0.573**	9.5
49	<i>Pseudorhombus arsius</i>	109	1, 3	2	0.287*	4.1
50	<i>Priopidichthys</i>	106	1,2	3	0.813**	7.8
51	<i>O. interrupta</i>	106	2,3	2	0.619**	10.1
52	<i>Upeneus</i>	105	1, 3	2	0.179	
53	<i>Alima</i>	104	1,2	2	0.645**	9.8
54	<i>Suggrundus</i>	98	3	1	0.538**	8.7
55	<i>Octopus</i>	97	3	2	0.285*	3.5
56	<i>Minous</i>	74	3	1	0.061	
57	<i>Odontodactylus</i>	69	3	1	0.740**	10.4
58	<i>Siganus</i>	55	1,2	6	0.423**	0.7
59	<i>Dorippe</i>	52	1	3	0.178	
60	<i>Alpheus distinguendus</i>	51	2,3	2	0.152	
61	<i>Sillago ciliata</i>	50	1,2	2	0.480**	7.7
62	<i>Thenus</i>	45	1, 3	3	0.256	
63	<i>Scyllarus</i>	44	1	3	0.009	
64	<i>Phalangipus</i>	38	1	1	0.070	
65	<i>Cepola</i>	33	3	3	0.754**	12.2
66	<i>Portunus rubromarginatus</i>	29	3	2	0.839**	8.9

67	<i>Parapercis</i>	27	3	1	0.337*	4.0
68	<i>Penaeus merguensis</i>	26	1	2	0.175	
69	<i>Cynoglossus</i>	25	3	2	0.213	
70	<i>Anchisquilla</i>	11	3	1	0.088	

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